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Space 'beachballs' generate pulsar bursts

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Astronomers have tracked the long-sought source of brilliant beams that bounce across galaxies from super-dense spinning star remnants called pulsars to structures no bigger than a beachball.

The tracing of the bright signals that wink through space like a lighthouse through mist to the smallest objects ever detected outside the solar system helps illuminate one of the most exotic environments ever perceived, researchers told United Press International.

Born in the death throes of a massive star -- at least eight times the size of the sun -- as it exploded in celestial fireworks known as a supernova, a pulsar spews sprays of radio waves and light.

A supernova marks the farewell flicker -- albeit a tremendously luminous one -- of a star running on empty. Its nuclear fuel exhausted, the star -- if its core is sufficiently heavy -- collapses on itself, expelling a great belch that spits the stellar shell into space. The blowout releases so much energy the dying star briefly can outshine its entire host galaxy. By nature's rules that still need clarifying, some of these remnant neutron stars take the form of pulsars.

Since their discovery in 1967 -- a find deemed worthy of a Nobel prize -- pulsars have challenged scientists to solve the mystery of how they produce their powerful beams of electromagnetic radiation. The new work provides a key piece to the puzzle that has frustrated physicists for nearly four decades.

"Efforts to understand pulsars and their emission have proved so very difficult that only limited progress has been made over the last several decades," Joanna Rankin, a physicist at the University of Vermont, told UPI. "This result is certainly exciting. It offers new and fundamental tools for understanding the pulsar environment and pulsar emission."

The conclusions come from a study by scientists at the New Mexico Institute of Mining and Technology in Socorro. Using specialized electronic equipment at the Arecibo Observatory in Puerto Rico, they analyzed radio emissions from a pulsar at the center of the Crab Nebula, a cloud of glowing debris from a supernova blast 6,000 light-years away, on extremely small time scales.

A light-year is the distance traversed in one year by light traveling at 186,282 miles (299,972 kilometers) per second, or some 5.88 trillion miles (9.46 trillion km).

The researchers broke down into tiny time segments the star's giant pulses, noting a series of nearly imperceptible "subpulses" that last no longer than 2 nanoseconds. A nanosecond is one-billionth of a second. As a point of reference, it takes 15-to-20-thousandths of a second for an automobile's airbag to deploy.

The space sleuths speculate their finding means the regions in which these ultra-short pulses are generated can be no larger than about 2 feet (0.6 meters) across -- the distance light travels in 2 nanoseconds.

"None of the other proposed mechanisms can produce such short pulses," noted Jean Eilek, professor of physics and member of the team that investigated the pulsar that spins 33 times every second. "The ability to examine these pulses on such short time scales has given us a new window through which to study pulsar radio emission."

The researchers regard their results as critical to comprehending the origin of the enigmatic emissions, as well as to gleaning clues to other unsolved mysteries.

"The electric, magnetic and gravitational fields near a pulsar are among the strongest known in the universe," said study leader Tim Hankins, a physics professor who was a visiting scientist at Arecibo when the telling observations were made, in March and May of 2002. "So the environment provides a test ground for 'extreme physics.'"

To investigator Jeff Kern, a graduate student at the New Mexico Institute of Mining and Technology and a predoctoral fellow at the National Radio Astronomy Observatory, both in Socorro, the region that generates a pulsar's radio waves represents "the most exotic environment in the universe."

There, above the neutron star's magnetic poles in the so-called magnetosphere, matter exists as plasma. In this highly charged gas, the properties are so distinct from those of the ordinary solid, liquid and gas phases that many physicists consider plasma a fourth state of matter.

Free from the usual constraints, electrically charged atoms can partake in a particle free-for-all driven by the mighty electric and magnetic fields in the star's atmosphere.

The mini-pulses detected by the researchers could only be generated in this region, they said. They are the produce of a strange process, in which density waves in the plasma interact with their own electrical field, cramming together to a breaking point. The ensuing explosion emits super-strong bursts of radio waves, they added.

"The computer solutions show how waves generated in the plasma by the flow of particles develop a turbulent state," noted James Weatherall, an adjunct professor of physics at New Mexico Tech. Weatherall, who now works for the Federal Aviation Administration, proposed the scenario.

"In the turbulent state, the waves strongly interact to form peaks of intense, localized electric field," he told UPI, citing an ocean tsunami as a familiar example of the process. "The simulations show how the 'collapse' of these strong field regions produce the small spatial structure and intensity seen in the radio observations."

Although it is premature to discount all other possibilities, Kern told UPI, "for now it looks as though the mechanism we propose is probably correct."

The results provide a fresh perspective to the perplexing pulsar emission puzzle, said Roger Romani, associate professor of physics at Stanford University in Palo Alto, Calif.

"The interpretation here looks appealing," he told UPI, "although further predictions and tests will have to be made for it to carry the day."

Scientists urged caution in drawing broad conclusions from findings relating to a pulsar as atypical as the one under study.

"The Crab is one of the most unusual pulsars known," noted Bryan Gaensler, professor of astronomy at Harvard University in Cambridge, Mass.

At 949 years of age -- born of a July 4, 1054, supernova explosion recorded by Earth-bound eyewitnesses -- it is one of the youngest of the 1,500 pulsars discovered thus far. Most of the others have been pulsing away for millions to billions of years.

It also is one of only three known spinning neutron stars shown to produce the super-strong, giant pulses.

"It was long held up as representative of the population, but is now known to be anomalous in almost every respect," Gaensler told UPI. "While these results appear fascinating in their own right, I would be cautious of applying anything learned from the Crab pulsar to other sources."

Indeed, the pulsar's bright, brief flashes are second only to the sun in their radio radiance in the sky, the authors pointed out in their report, which will be published in the March 13 issue of the British journal Nature.

Although the mechanism that converts the plasma energy to radio waves in the big beams might be unique to the neutron star they observed, the researchers added, it is feasible all radio pulsars could operate the same way.

"The Crab pulsar exhibits many of the same radio emission characteristics as the other known pulsars," Hankins told UPI, "so we think that the radio emission mechanism is probably similar to the other pulsars."

Stephen Thorsett, associate professor of astronomy and astrophysics at the Santa Cruz Institute for Particle Physics at the University of California, Santa Cruz, sees the work as key to unlocking new research opportunities.

"These techniques have a lot of promise for helping us figure out how pulsars work," he told UPI, "especially when larger radio telescopes -- like the planned Square Kilometer Array (which is to have 20 times the sensitivity of the largest radio telescope now in operation) -- let them extend their work to a bigger set of fainter pulsars."

The team is now observing signals from other pulsars to see if they are fundamentally different. The Crab's micro-pulses are so strong their instruments could detect them even if they originated outside of the Milky Way galaxy, the researchers said.

In another project, a major search effort under development at Arecibo is expected to increase the number of known pulsars to 5,000 or even 10,000 in the next five years, Kern said.

"This sort of study will not end world hunger," Romani concluded, "but if the 'coolness' of seeing ultra-bright beachball-sized plasma clouds thousands of light years away captures some young person's imagination and encourages them in technical pursuits, that's a good day's work."

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